Effects of Off-road Vehicles on Rodents in the Sonoran Desert

by

John Simon Reid

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Graduate Supervisory Committee:

Ward Brady, Chair
Heather Bateman
William Miller

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ABSTRACT

Human recreation on rangelands may negatively impact wildlife populations. Among those activities, off-road vehicle (ORV) recreation carries the potential for broad ecological consequences. A study was undertaken to assess the impacts of ORV on rodents in Arizona Uplands Sonoran Desert. Between the months of February and September 2010, rodents were trapped at 6 ORV and 6 non-ORV sites in Tonto National Forest, AZ. I hypothesized that rodent abundance and species richness are negatively affected by ORV use. Rodent abundances were estimated using capture-mark-recapture methodology. Species richness was not correlated with ORV use. Although abundance of *Peromyscus eremicus* and *Neotoma albigula* declined as ORV use increased, abundance of *Dipodomys merriami* increased. Abundance of *Chaetodipus baileyi* was not correlated with ORV use. Other factors measured were percent ground cover, percent shrub cover, and species-specific shrub cover percentages. Total shrub cover, *Opuntia* spp., and *Parkinsonia microphylla* each decreased as ORV use increased. Results suggest that ORV use negatively affects rodent habitats in Arizona Uplands Sonoran Desert, leading to declining abundance in some species. Management strategies should mitigate ORV related habitat destruction to protect vulnerable populations.

This is dedicated to my mother, Sarah Gilmer Reid, who instilled in me an abiding respect for nature, and a mindset for conservation. She is greatly missed. Also for Michelle Lanier, my partner in love and life, whose love and support have helped make this possible.

ACKNOWLEDGMENTS

I would like to thank my major professor, Dr. Ward Brady, whose guidance and insight contributed greatly to this project. Thank you also to my committee members, Dr.'s Heather Bateman and Bill Miller, whose advice has been invaluable. I also would like to thank Liz Krone, a fellow graduate student who assisted me in the field.

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CHAPTER 1

INTRODUCTION

Balancing human activities within ecological systems is paramount to the conservation of biodiversity on a global scale. Among all current threats to global biodiversity, habitat loss has been identified as the greatest (Wilcove et al 1998). Identifying direct causes of habitat loss, and assessing the impacts on local wildlife populations should therefore be part of any wildlife conservation strategy. In the United States, public lands constitute an important reservoir of biodiversity (Stein et al. 2008). Human activities on public lands should be closely monitored, and regulated where necessary, to assess and mitigate resulting habitat loss.

Among the many forms of outdoor recreation common to public lands, the use of off-road vehicles (ORV) is uniquely destructive to habitats. When driven away from established roads, these vehicles destroy vegetation, damage soils, alter erosion patterns, and disturb wildlife (Iverson et al 1981, Luckenback and Bury 1983). Such impacts may change landscapes, altering the ecology of an area for years to come (Knapp 1992). The idea that ORV may negatively impact the biodiversity of an area is not new, but given the popularity of this sport on public lands, it is important to understand the details of these impacts in order to make informed management decisions.

This study seeks to quantify the impacts of ORV use on rodents in Arizona Uplands Sonoran Desert. It was hypothesized that areas heavily disturbed by ORV usage would show lower rodent abundances and lower species diversity than relatively undisturbed habitats that are similar otherwise. It was also hypothesized that shrub and ground cover would decrease as ORV disturbance levels increased.

Rodents were chosen as a study subject because of their important ecological roll as a primary consumer. Compared to mesic environments, rodents make up a larger portion of the mammalian community in arid lands, both in biomass and diversity (Van der Valk 1997). Given the relative importance of rodents to desert communities, coupled with the fragility of arid environments (Stebbins 1974), human activities that negatively affect desert rodent populations carry the potential for broad ecological consequences. Mammalian communities in North American deserts are dominated by grainivorous rodents, which rely heavily on abundant perennial seed crops (Brown et al 1979). If ORV use negatively affects perennial shrub cover in the study area, rodent populations may decline. With the immense popularity and potential destructiveness of ORV, it is critical that scientists and wildlife managers understand the effects on rodent communities.

This study will benefit those interested in managing wildlife populations that are significantly affected by human recreation. Although the destructive nature of ORV recreation is well documented, quantitative data describing both direct and indirect effects on wildlife is scarce. Possible cascading ecological consequences are especially relevant when important communities, such as desert rodent populations, are negatively impacted. This study adds to previous efforts in its attempt to correlate population impacts with ORV use on a continuous scale. With ORV use increasing in North America (Bowker *et al*. 1999), an understanding of the wildlife impacts is essential to making informed management decisions.

CHAPTER 2

LITERATURE REVIEW

Research on the effects of ORV use on wildlife generally focuses on beaches along the U.S. Atlantic coast (Burger and Gochfeld 1990, Patterson et al 1991, Melvin et al.1994, McGowan and Simons 2006, Hobbs et al 2008), or on arid regions of the U.S. southwest (Bury 1978, Luckenback and Bury 1983, Brooks 1992, Beauchamp et al 1998, Barton and Holmes 2007,Tull and Brussard 2007). Typically, western studies have occurred in California's Colorado Desert, Great Basin Desert, or in various regions of the Mojave Desert. Studies of ORV use in forest habitats have not consistently reported significant effects of ORV on local wildlife (Zielinski et al. 2008, Naylor et al. 2009). No previous study could be found of ORV effects in Arizona Uplands Sonoran Desert. The high plant biodiversity of Arizona Uplands Sonoran Desert may decrease the amount of off-trail driving compared with other North-American deserts, as it lacks the open spaces of these more sparsely vegetated deserts. It remains unclear if the densely vegetated deserts of upland Arizona are more resilient to ORV disturbance than other deserts. Although this study does not seek to compare the effects of ORV between different deserts, the results have implications that may lead to further study in this area.

Previous studies have found that ORV use negatively affects wildlife in arid lands. Luckenback and Bury (1983) trapped small mammals at Algodones Dunes in southeastern California and surveyed lizards.

They found that species diversity and abundance in both groups were negatively affected by ORV use. Tull and Brussard (2007) found no effect on abundance of western fence lizards (*Sceloporus occidentalis*), but they did note increased asymmetry of dorsal scales, a measure of stress in lizards, related to ORV use in the western Great Basin Desert. Songbird abundance and nesting success were negatively correlated with proximity to ORV trails in northern Great Basin Desert (Barton and Holmes 2007). In an ORV recreation area near Borrego Springs, CA, habitat use by flat-tailed horned lizards (*Phrynosoma mcallii*) differed from the usual habitat characteristics for the species (Beauchamp et al 1998). Researchers hypothesized that heavy ORV use in preferred habitat may have pushed the population into marginal areas, not commonly associated with this species. In the western Mojave Desert, several surveys reported higher densities of desert tortoises (*Gopherus agassizii*) in areas with no ORV usage than in areas with high ORV usage (Bury 1978). A comparison of small-mammal abundance in a grazing/ORV exclosure area near California City, CA showed significantly higher densities of Merriam's kangaroo rats (*Dipodomys merriami*), long-tailed pocket mice (*Chaetodipus formosus*), and southern grasshopper mice (*Onychomys torridus*) in the exclosure compared to paired plots where grazing/ORV occurred, though the author did not isolate the effects of each disturbance type (Brooks 1992).

Many studies find negative impacts of ORV on wildlife inhabiting beaches along the U.S. Atlantic seaboard. Melvin et al. (1994) documented 14 cases of ORV related mortality in piping plovers (*Charadrius melodus*) on beaches in Massachusetts and New York. In coastal North Carolina, ORV were often a factor (25%) in nest leaving by American oystercatchers (*Haematopus palliatus*), which was negatively associated with nest survival (McGowan and Simons 2006). Nest success in least terns (*Sternula antillarum*) decreased with proximity to ORV trails in New York and New Jersey (Burger and Gochfeld 1990). Restricting ORV beach access led to a significant increase in mean ghost crab (*Ocypode quadrata*) burrow density at Cape Hatteras National Seashore, NC (Hobbs et al 2008). Conversely, ORV had no effect on *C. melodus* productivity on Assateague Island (MA/VA), though nest sites were generally protected from direct vehicular contact by fencing or regulation (Patterson et al 1991).

No ORV related impacts were observed on American martens (*Martes americana*) in high-elevation forests near Lake Tahoe, CA, though ORV use was light in the study areas (Zielinski et al. 2008). In a study of recreational impacts on elk (*Cervus canadensis*) in northeastern Oregon, radio collared animals were disturbed by ORV use, causing an increase in travel time and a decrease in feeding time, thus increasing total energy expenditure as a direct result of proximity to ORV use (Naylor et al. 2009). In a review of literature pertaining to the interface between recreation and wildlife, Boyle and Samson (1985) found that ORV use often negatively impacts terrestrial vertebrates, though they point out inconsistencies and a lack of quantitative data. Overall, off-road vehicles are implicated in the decline of approximately 13% of endangered species in the United States (Wilcove et al. 1998).

Many authors discuss the need for more research into the effects of ORV use on wildlife (e.g. Barton and Holmes 2007, Tull and Brussard 2007, Zielinski et. al. 2008). Previous quantitative studies of the impacts of ORV use on wildlife report differences in abundance between use and non-use areas (e.g. Luckenback and Bury 1983, Tull and Brussard 2007), or declining abundance with closer proximity to ORV trails (Barton and Holmes 2007) but do not examine finer-scale relationships between amount of ORV use and abundance.

CHAPTER 3

STUDY AREA

Research was conducted from February-September, 2010 in Tonto National Forest, 30 km northeast of Fountain Hills, AZ in Maricopa County. The study area lies in Arizona Uplands subdivision of the Sonoran Desert (Brown 1982). ORV usage areas were located east of Cottonwood Creek campground in the Rolls ORV recreation area. Non-usage areas were located in Four Peaks Wilderness, west of the undeveloped campground. ORV use is prohibited in Four Peaks Wilderness. Study areas were desert scrub communities separated by Cottonwood Creek, an intermittent desert stream.

Geographically, the study area is located in the bajadas stretching southwest from the base of Four Peaks, a north-south ridge of the Mazatzal Mountains, to the Salt River. Dominant overstory vegetation included foothills paloverde (*Parkinsonia microphylla.)*, desert hackberry (*Celtis pallida*), whitethorn acacia (*Acacia constricta.)* and Gregg's catclaw (*Acacia greggii*). Also present were giant bursage (*Ambrosia ambrosioides)*, saguaro (*Carnegiea gigantea*), burrow brush (*Hymenoclea monogyra*), Ocotillo (*Fouquieria splendens*), honey mesquite (*Prosopis glandulosa*), jojoba (*Simmondsia chinensis*), turpentine bush (*Ericameria laricifolia*), and various cholla and prickly pear (*Opuntia* spp.). Elevation ranged from 610-770 m.

The Rolls ORV recreation area experiences heavy ORV usage, concentrated along roads and trails, but off-trail use is also common despite legal requirements for vehicles to stay on existing trails. Wilderness areas were demarcated by signage prohibiting vehicle use, and by fencing, but vandalism of signs and fencing is common and vehicles were occasionally seen in prohibited areas. Overall ORV usage in the wilderness appeared to be infrequent. Other recreational activities commonly observed in the area included target shooting, camping, and horseback riding.

For purposes of the study, the area was divided into three habitat types, which included riparian, wash, and ridge. Riparian habitat was immediately adjacent to Cottonwood creek with *P. glandulosa* and *C. pallida* being dominant plant species. Wash habitat described flat, sandy wash bottoms that drained into cottonwood creek. *Acacia greggii*, *A. constricta*, and *P. microphphylla* were dominant plant species in wash habitat. Ridge habitat occurred on the slopes and hilltops above washes and was generally rockier than other habitat types. Ridge habitat was characterized by the presence of *S. chinensis*.

CHAPTER 4

METHODS

A capture-mark-recapture methodology was used to compare rodent populations in ORV disturbed areas with those in non-disturbed areas. Permission to conduct animal research was given by the Institutional Animal Care and Use Committee at Arizona State University (appendix A), the Arizona Department of Game and Fish (appendix B), and Tonto National Forest, Mesa Ranger District. Animals were trapped monthly from February 2010-June 2010 and again in September 2010. Animals were captured with long Sherman live traps, chosen to eliminate tail severing and reduce mortality in larger rodents (Slade *et al.* 1993).

Trapping locations were paired through the study time such that at any one time the same habitat was being sampled in the ORV and non-ORV areas. Suitable trapping locations had to be physically accessible, which biased sampling to areas where one could physically transport equipment from a vehicle. Distances between paired habitat grids had to be small enough to allow two areas to be sampled quickly, reducing mortality to trapped animals. In order to randomize trapping areas, satellite images of suitable locations were overlaid with a half-inch grid pattern. The image was then studied, and any grid-square deemed unsuitable for trapping because of steep terrain was eliminated. Remaining grid-squares were numbered, and a single square was chosen for sampling with a random number generator. Viewing landmarks in the chosen sample area allowed determination of a GPS point at the approximate center of a square using mapping software. This GPS point was chosen as the location of the first trap in a grid.

Traps were laid out in a 7x5 grid pattern with 35 traps per grid and approximately 10 m between traps. Orientation of trap grids varied with terrain, as an effort was made to contain each sampling area within a homogeneous habitat while maintaining a uniform grid area between sample locations. Distance between traps was estimated by taking 10 full paces between trap location points, and between the end of a trap line and the start of the next line. Distance between traps varied when terrain or vegetation made the next trap location too difficult to access. In these situations, the trap was placed as close as possible to where it would have been placed absent these obstacles.

Both use and non-use areas were subdivided into the following habitat categories: wash, riparian, and ridge. Categorical subdivisions across the usage gradient were always sampled concurrently; which added a blocking effect in an effort to remove variation in rodent populations due to time of year or habitat changes within the study area (Table 1). Each trap grid was sampled for 6 consecutive nights. Traps were set each evening and baited with rolled oats. Cotton balls were added to the traps to provide nesting material. Traps were checked each morning, beginning at dawn.

Table 1. Trapping schedule for 12 randomly selected areas sampled during a capture-mark-recapture study conducted in Rolls ORV Recreation Area and Four Peaks Wilderness, Tonto National Forest, USA, Feb-September, 2010. Sample locations were paired so that similar habitats were sampled concurrently across the off-road-vehicle (ORV) usage gradient. Location coordinates are included for the center of each 7x5 trap grid.

Sample Date	Habitat	ORV allowed	Latitude	Longitude
Feb 6-11	Wash	Yes	33°37'20.05"N	111°27'2.33"W
Feb 6-11	Wash	No	33°37'35.28"N	111°26'19.25"W
Mar 25-30	Riparian	Yes	33°37'30.84"N	111°26'53.20"W
Mar 25-30	Riparian	No	33°37'44.20"N	111°26'49.11"W
Apr 27-May 2	Ridge	Yes	33°38'28.68"N	111°28'36.33"W
Apr 27-May2	Ridge	No	33°37'25.63"N	111°26'44.55"W
May 11-16	Riparian	Yes	33°37'17.46"N	111°26'50.07"W
May 11-16	Riparian	No	33°37'26.21"N	111°26'48.74"W
June 11-16	Wash	Yes	33°37'20.45"N	111°26'56.84"W
June 11-16	Wash	No	33°37'33.70"N	111°26'27.80"W
Sept 18-23	Ridge	Yes	33°37'59.20"N	111°28'7.36"W
Sept 18-23	Ridge	No	33°37'30.97"N	111°26'34.12"W

The first three days of each trapping session was the initial capture period. Recaptures during this period were not recorded. Captured animals were marked with a permanent marker ventrally and on the ear for the purpose of estimating abundance based on recapture rate. During the following three-day recapture period, animals were marked with a different color, which changed daily. The color of markings on an animal indicated the number of times it had been captured, and an absence of markings indicated a newly captured animal. Injured animals were euthanized in compliance with IACUC guidelines.

Presence or absence of ORV disturbance was characterized by visual survey. Each trap grid consisted of 24 habitat squares, which were visually inspected for signs of ORV use, such as tire tracks. Disturbance was quantified for each trap grid as a percentage of habitat squares that were disturbed.

Vegetation was sampled in each trap grid. Shrub cover was measured using a line-intersect method along randomly selected 30 m transects. To randomize transect locations, numbered traps were selected with a random number generator to serve as transect start-points. Each transect extended in a randomly selected direction (1°-360°) from the start point. Length of transect-line intercept, along with species, was recorded for each shrub or tree intersecting the transect. Groundcover percentage was characterized along the same 30 m transects by the Daubenmire method (Daubenmire 1959). Daubenmire plots were laid out at 3 m intervals for a total of ten plots sampled per transect. Grids were sampled until the running mean varied by less than 5% between transects, with an average of 3 transects per grid.

DATA ANALYSIS

Rodent abundances were estimated using the Lincoln Petersen method. Species diversity was measured with Simpson's Diversity Index (Simpson 1949). Statistical analysis was completed using R project for statistical computing (R Development Core Team 2008).

It was assumed that for each species of rodent, abundances will likely differ both between habitats and over time. Neither of these differences is pertinent to the research question of this study, therefore, Rodent data were analyzed with a paired t-test, with samples divided between ORV use areas, and wilderness areas where ORV use was prohibited. Significance levels for individual tests were adjusted using the formula:

$$\alpha(\text{overall}) = 1 - (1 - \alpha)^n, \text{ (where n = the number of tests)}$$

to give an overall $\alpha = 0.10$ for the group of tests (Abdi 2007). For the rodent data, tests were conducted on abundance of the four major species and on species diversity using $\alpha = 0.021$ for each test, resulting in an overall $\alpha = 0.10$. Rodent data were further analyzed with simple regression models, in which abundance and diversity were dependent variables and ORV disturbance percentage was the independent variable.

Vegetative data were also analyzed with paired t-tests and by simple regression, with the same independent variables used in the rodent models. Dependent variables used in the vegetative models were percent shrub cover, percent ground cover, and percent cover by each genera of shrub most common to the study area with $\alpha = 0.017$ for each individual test.

ORV disturbance levels were compared between habitats by analysis of variance (ANOVA) to determine if ORV users preferred a particular habitat block within the study area. Only areas sampled within the Rolls ORV recreation area were included in the ANOVA since ORV use was uncommon in the wilderness area.

CHAPTER 5

RESULTS

We had 789 captures of 557 individuals, representing 10 species (Table 2). Mortality rate for the study was 4.13%. No relationship was apparent in the regression model comparing rodent diversity to ORV disturbance levels ($p = 0.329$, Table 3), and rodent diversity did not differ significantly between ORV use and non-use areas ($p = 0.535$, Table 4). Additional results are reported for the four most commonly captured species.

Table 2. Number of rodents captured in the Rolls ORV Recreation Area and Four Peaks Wilderness, Tonto National Forest, USA, Feb-September, 2010.

Species	Number Captured	Mortality
Perognathus longimembris	6	0
Perognathus amplus	24	0
Onychomys torridus	16	0
Neotoma albigula	82	2
Chaetodipus penicillatus	27	0
Chaetodipus baileyi	201	11
Dipodomys merriami	130	9
Peromyscus eremicus	62	0
Ammospermophilus harrisii	8	1
Tamius dorsalis	1	0
Total	557	23

Table 3. Summary of results from simple regression models (N=12, α = 0.10) comparing rodent population response variables (diversity and abundance) to off-road vehicle (ORV) disturbance levels during an ORV impact study conducted in Four Peaks Wilderness and Rolls ORV Recreation Area, Tonto National Forest, USA, Feb-September, 2010.

Response Variable	R^2	F-value	df	Slope of Regression	p-value
Rodent Diversity	0.0951	1.05	1,10	-0.00123	0.329
Dipodomys merriami	0.522	10.9	1,10	+0.235	0.00798
Chaetodipus baileyi	0.157	1.86	1,10	-0.145	0.203
Neatoma albigula	0.268	3.66	1,10	-0.134	0.0846
Peromyscus eremicus	0.395	6.53	1,10	-0.140	0.0287

DIPODOMYS MERRIAMI

Abundance of Merriam's kangaroo rat (*D. merriami)* showed significant departure from the null hypothesis with respect to disturbance in the regression model (P = 0.00798, Table 3). Areas with higher levels of ORV disturbance generally had larger estimated *D. merriami* populations (Figure 1). Though a significant trend is apparent in the linear model, t-tests did not show a significantly higher mean abundance of *D. merriami* in the Rolls ORV Recreation area than in Four Peaks wilderness (p = 0.0580, Table 4).

CHAETODIPUS BAILEYI

Bailey's pocket mouse (*C. baileyi*) abundance was not significantly correlated with ORV disturbance in the linear model (p = 0.203, Table 3).

Additionally, results of the t-test do not reveal a significant difference between *C. baileyi* abundance in ORV use areas versus non-use areas ($p = 0.199$, Table 4).

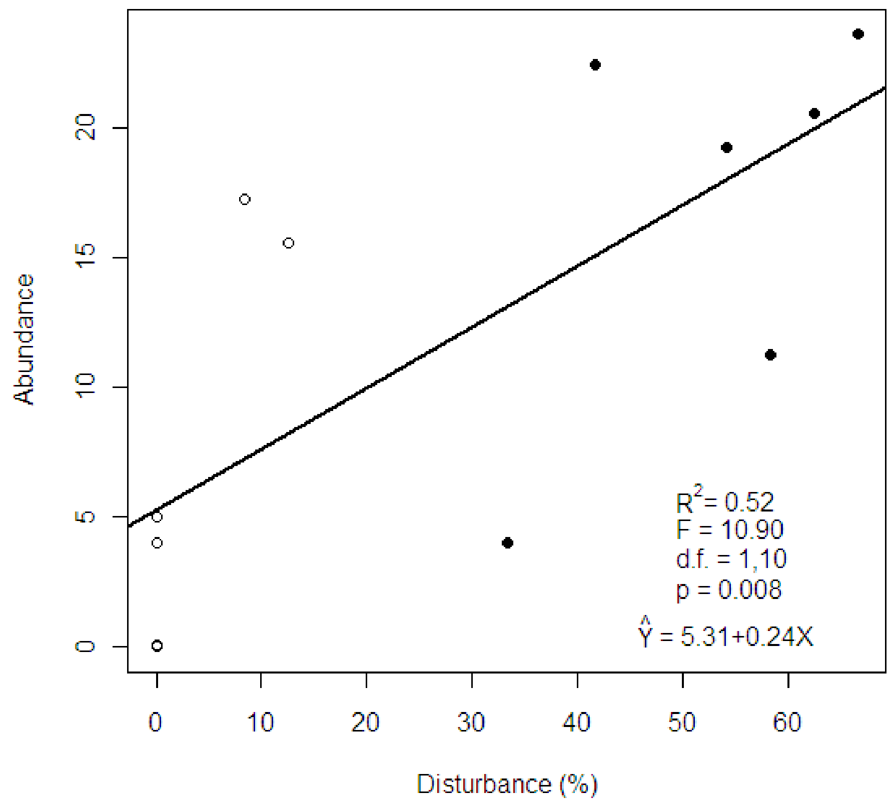

Figure 1. Relationship between off-road vehicle disturbance percentage and estimated abundance of *Dipdomys merriami* at 12 randomly selected locations, which were sampled during a capture-mark-recapture study conducted in Rolls ORV Recreation Area (●) and Four Peaks Wilderness (○), Tonto National Forest, USA, Feb-September, 2010.

Table 4**.** Summary of results from student's t-tests (N = 12, df = 5, α = 0.021) comparing rodent population response variables (diversity and abundance) for each area sampled during an off-road vehicle (ORV) impact study conducted in Four Peaks Wilderness and Rolls ORV Recreation Area, Tonto National Forest, USA, Feb-September, 2010.

Response Variable	Four Peaks Mean(SE)	Rolls Mean(SE)	t-value	p-value
Rodent Diversity	0.317(0.0392)	0.293(0.0527)	0.665	0.535
Dipodomys merriami	6.98(3.11)	16.858(3.13)	2.45	0.0580
Chaetodipus baileyi	24.4(4.65)	17.208(3.20)	1.48	0.199
Neatoma albigula	11.0(3.60)	4.583(1.21)	1.70	0.151
Peromyscus eremicus	10.2(2.49)	2.167(1.01)	3.47	0.0179

NEOTOMA ALBIGULA

Abundance of white-throated wood rats (*N. albigula*) showed significant departure from the null hypotheses with respect to ORV disturbance In the linear model (P = 0.0846, Table 3). Differences in mean abundance of *N. albigula* in ORV areas versus non-ORV areas were not statistically significant (p = 0.151, Table 4). Subjective analysis of the regression plot suggests that abundance decreased as disturbance increased (Figure 2).

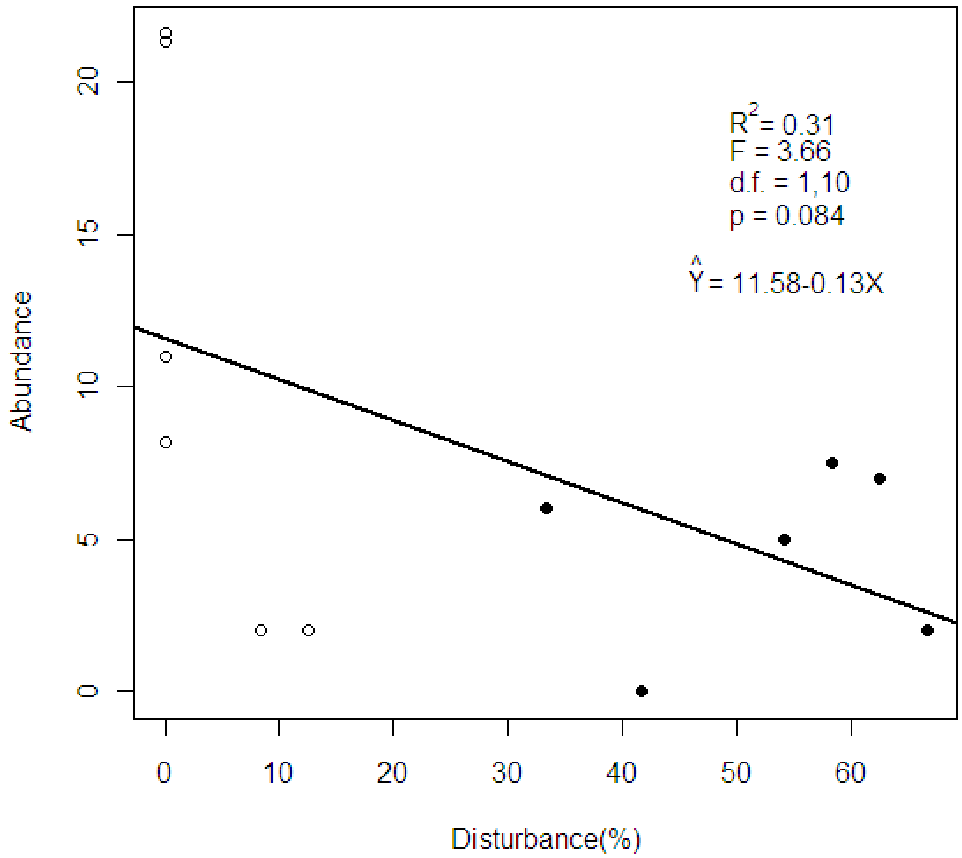

Figure 2. Relationship between off-road vehicle disturbance percentage and estimated abundance of *Neotoma albigula* at 12 randomly selected locations, which were sampled during a capture-mark-recapture study conducted in Rolls ORV Recreation Area (●) and Four Peaks Wilderness (○), Tonto National Forest, USA, Feb-September, 2010.

PEROMYSCUS EREMICUS

There was a significant linear relationship between Mean Cactus mouse (*P. eremicus*) abundance and ORV disturbance levels (p = 0.0287, Table 3). As disturbance increased, abundance of *P. eremicus* decreased (Figure 3). Abundance of *P. eremicus* also differed significantly between ORV use and non-use areas, according to the t-test (p = 0.0179, Table 4).

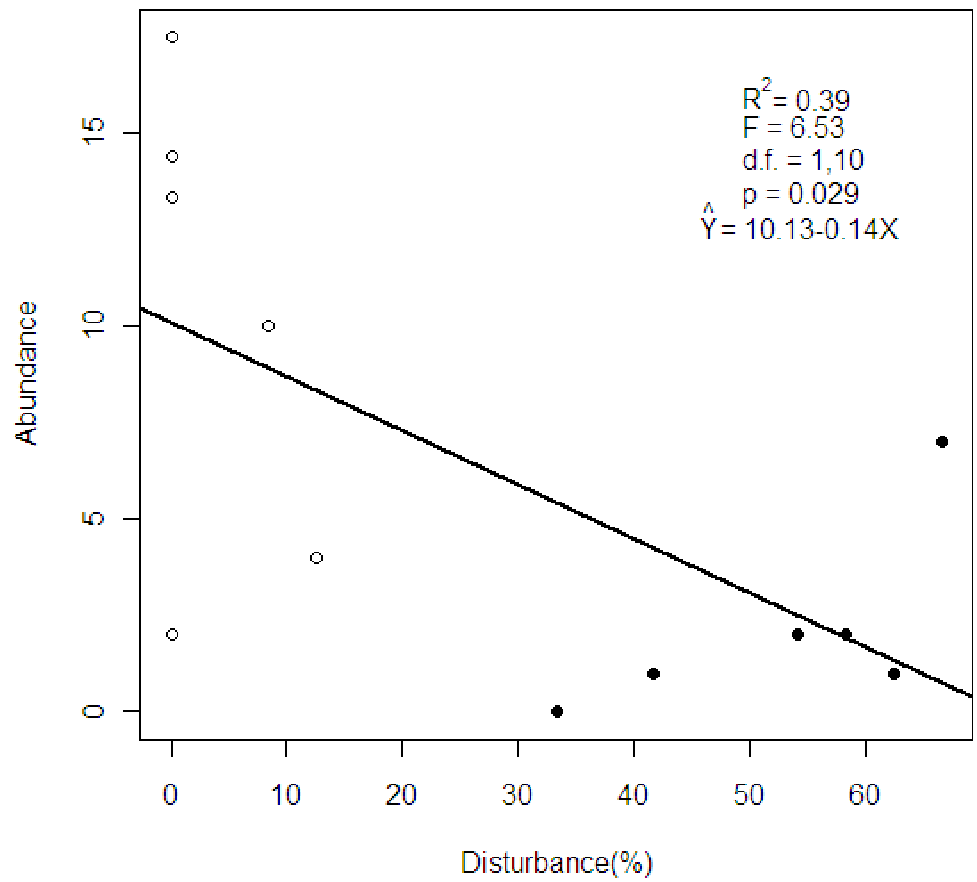

Figure 3. Relationship between off-road vehicle disturbance percentage and estimated abundance of *Peromyscus eremicus* at 12 randomly selected locations, which were sampled during a capture-mark-recapture study conducted in Rolls ORV Recreation Area (●) and Four Peaks Wilderness (○), Tonto National Forest, USA, Feb-September, 2010.

VEGETATION RESULTS

Results of the t-test for differences in mean shrub cover percentages in ORV use versus non-use areas indicate greater shrub density occurred in non-use areas (p = 0.0151, Table 5). In the regression model, the linear relationship between shrub cover and ORV disturbance percent is nearly significant (p = 0.116, Table 6). Subjective analysis of the regression model plot indicates a declining trend in shrub cover with increasing ORV use (Figure 4).

Table 5. Summary of results from student's t-tests (N = 12, df = 5, α = 0.017) comparing vegetation response variables (percent coverage) for each area sampled during an off-road vehicle (ORV) impact study conducted in Four Peaks Wilderness and Rolls ORV Recreation Area, Tonto National Forest, USA, Feb-September, 2010.

Response Variable	Four Peaks Mean(SE)	Rolls Mean(SE)	t-value	p-value
Shrub	42.3(4.04)	32.1(2.88)	3.63	0.0151
Ground	46.7(6.90)	37.3(7.62)	1.96	0.108
Acacia spp.	11.8(3.90)	13.0(2.75)	0.485	0.649
Ericameria laricifolia	4.39(1.75)	0.976(0.34)	2.03	0.099
Opuntia spp	3.67(1.12)	0.562(0.31)	2.81	0.0377
Parkinsonia microphylla	5.17(1.65)	0.169(0.17)	2.98	0.0309

Out of the 4 most common shrubs (those present in more than half of the study sites), only *Opuntia* spp. (P = 0.0389) and *Parkinsonia microphylla* (P = 0.0292) were significantly correlated with ORV disturbance in the regression model (Table 6). Densities of both shrubs decreased as ORV use increased (*O.* spp.: Figure 5, *P. microphylla*: Figure 6). Adjusted t-test α-values did not reach significance levels for any genera of shrub (Table 5).

Table 6. Summary of results from simple regression models (N=12, α = 0.10) comparing vegetation response variables (percent coverage) to off-road vehicle (ORV) disturbance levels during an ORV impact study conducted in Four Peaks Wilderness and Rolls ORV Recreation Area, Tonto National Forest, USA, Feb-September, 2010.

Response Variable	R^2	F-value	df	Slope of Regression	p-value
Shrub	0.229	2.97	1,10	-0.171	0.116
Ground	0.0151	0.154	1,10	-0.0793	0.703
Acacia spp.	0.00484	0.00484	1,10	+0.00634	0.946
Ericameria laricifolia	0.194	2.40	1,10	-0.0553	0.152
Opuntia spp	0.311	4.50	1,10	-0.0512	0.0598
Parkinsonia microphylla	0.395	6.52	1,10	-0.0868	0.0287

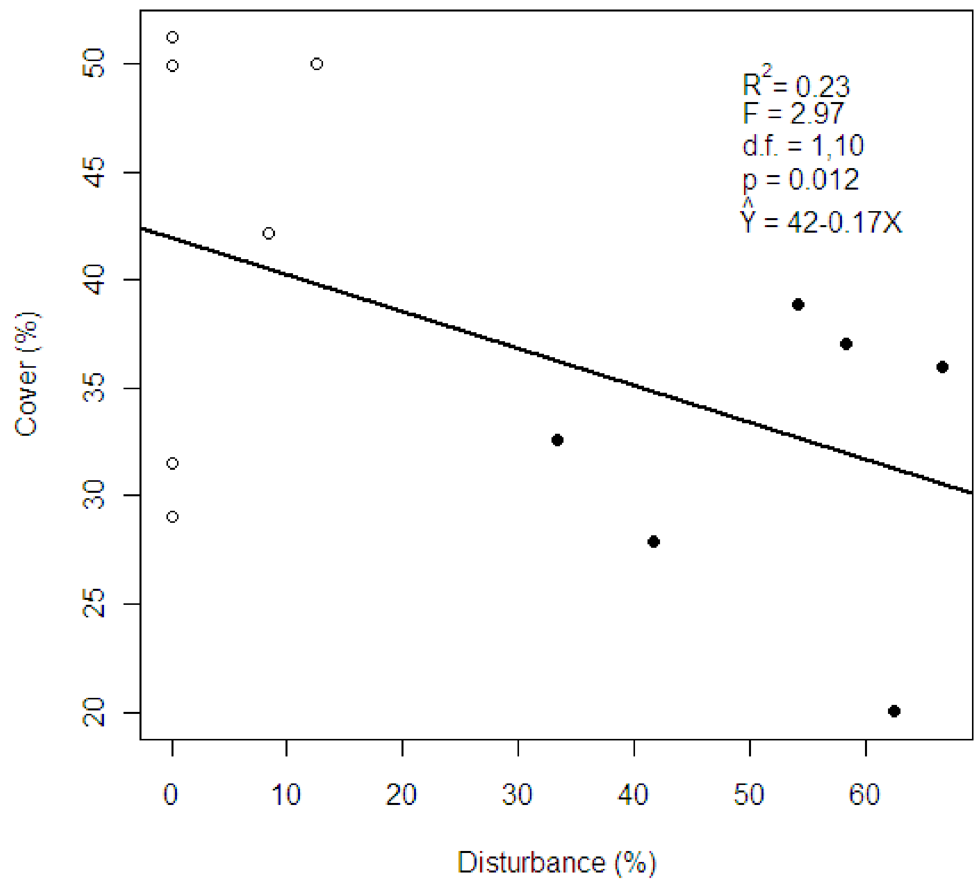

Figure 4. Relationship between off-road vehicle disturbance percentage and percent shrub cover at 12 randomly selected locations, which were sampled during an off-road vehicle impact study conducted in Rolls ORV Recreation Area (●) and Four Peaks Wilderness (○), Tonto National Forest, USA, Feb-September, 2010.

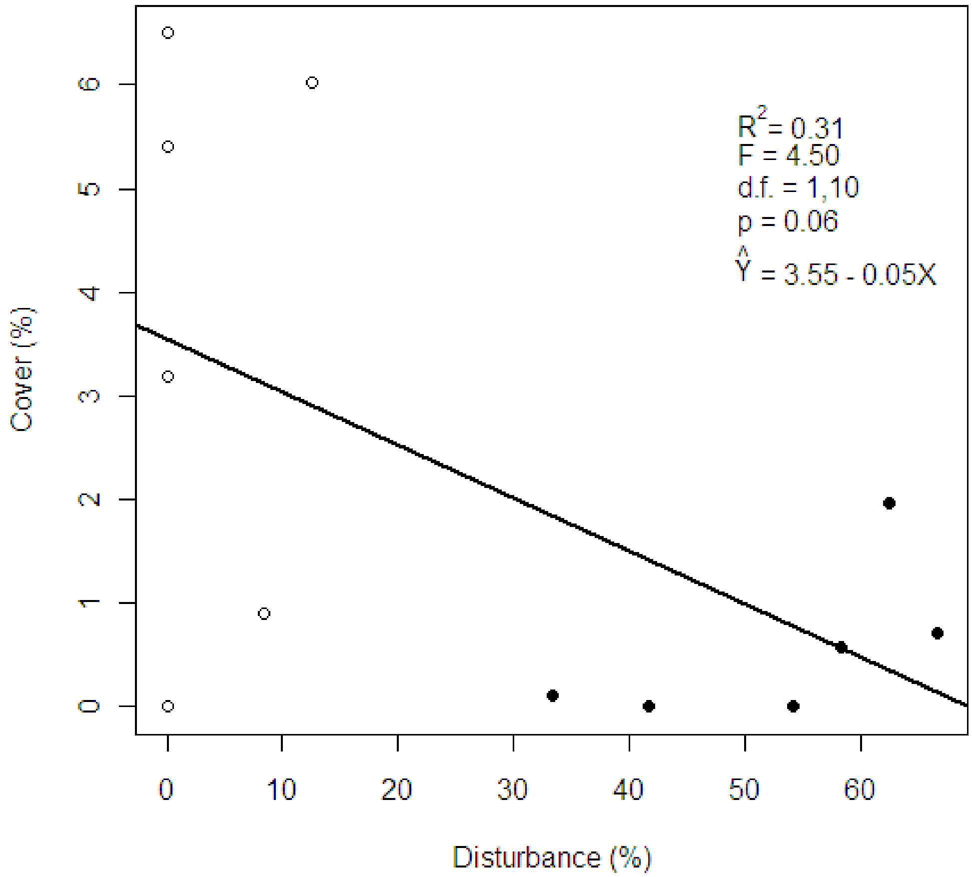

Figure 5. Relationship between off-road vehicle disturbance percentage and percent cover by *Opuntia* spp. at 12 randomly selected locations, which were sampled during an off-road vehicle impact study conducted in Rolls ORV Recreation Area (●) and Four Peaks Wilderness (○), Tonto National Forest, USA, Feb-September, 2010.

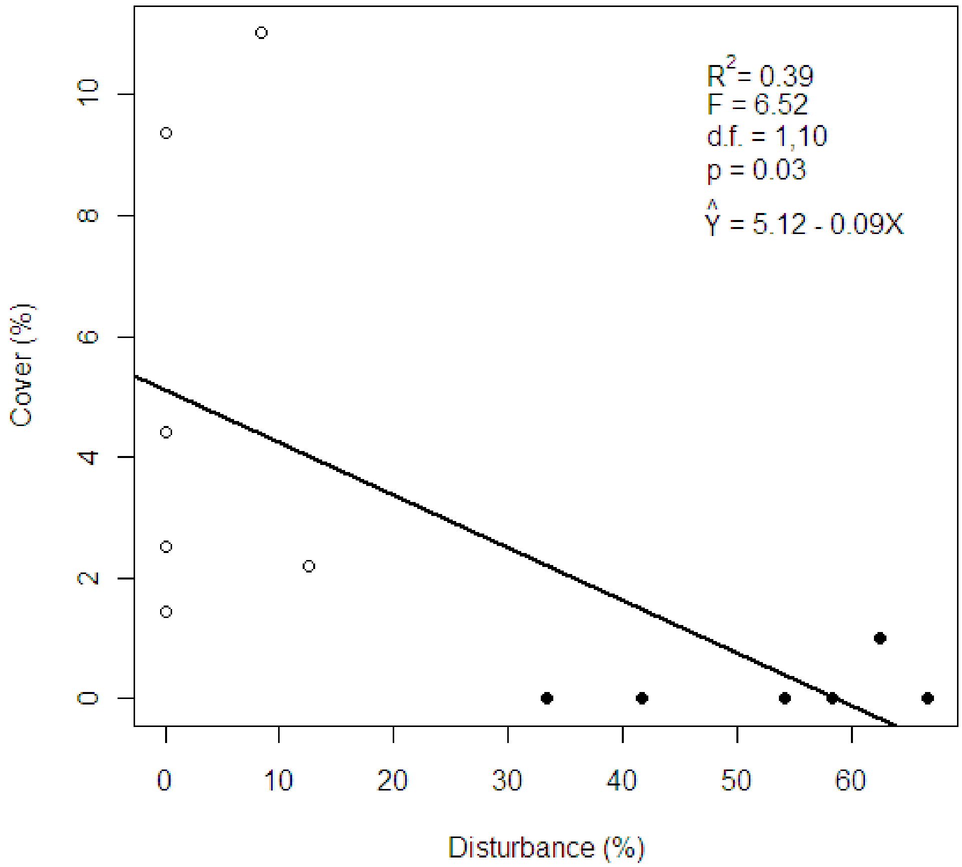

Figure 6. Relationship between off-road vehicle disturbance percentage and percent cover by *Parkinsonia microphylla* at 12 randomly selected locations, which were sampled during an off-road vehicle impact study conducted in Rolls ORV Recreation Area (●) and Four Peaks Wilderness (○), Tonto National Forest, USA, Feb-September, 2010.

CHAPTER 6

DISCUSSION

Study results partially supported the hypothesis that rodent abundance in Arizona Uplands Sonoran Desert is negatively affected by ORV use. While we did not find population effects for all species, and no significant effects for rodent diversity, for two species (*P. eremicus*, *N. albigula*) findings support previous studies showing depressed wildlife abundance in areas affected by ORV use (e.g, Luckenback and Bury 1983, Tull and Brussard 2007, Barton and Holmes 2007). This study adds to those previous studies in its attempt to identify possible mechanisms leading to observed population declines, including ORV related declines in vegetation density.

Abundance data for certain species did not support the hypothesis. Abundance of *C. baileyi* was unaffected by ORV use and abundance of *D. merriami* was positively correlated with ORV use. An understanding of the life histories of the species may explain the inconsistent effects of ORV use. Further discussion of results follows for each rodent species.

DIPODOMYS MERRIAMI

Although T-test results for this species were not significant, there was an apparently positive effect of ORV on *D. merriami* abundance in the regression model. The discrepancy in results between the two tests is not necessarily problematic, since t-tests grouped results dichotomously while the regression model analyzed ORV disturbance continuously. Additionally, our "non-ORV" area did receive some light ORV use. Increased *D. merriami* abundance in more heavily disturbed areas may be partially explained by its preference for sandy soils over desert pavement, gravelly or rocky soils (Hoffmeister 1986). A noticeable effect of ORV in the study area was a loosening of the topsoil in heavy usage areas, creating a sandier habitat than in the non-use area. Hoffmeister (1986) also finds that this species selects habitat where shrubs and grasses are interspersed with open areas, avoiding areas with dense grass cover. ORV sites were immediately discernable from non-use sites by a more clumpy vegetation pattern, where shrubs and grasses grew in dense patches separated by areas of open ground where ORV traffic was concentrated. Non-use areas showed a more uniform growth pattern with less open ground between plants, but smaller patches of dense vegetation.

The behavior of this species may also account for its success in ORV usage areas. Of all species, *D. merriami* showed the least agitation at being handled, and the most likely to openly forage occupied campsites. Increased refuse in ORV stressed habitat may provide better foraging opportunity for a species not naturally avoidant of human activity.

PEROMYSCUS EREMICUS

Other researchers have found increased abundance of *P. eremicus* associated with increased vegetative cover (MacMillen 1964, Bradley and

Mauer 1973, Van de Graff 1973). In a study of post-fire microhabitat selection by rodents in a coastal California sage scrub community, Price and Waser (1984) found that *P. eremicus* preferentially selected microhabitats characterized by shrubs or by grasses and forbs over open ground. Although shrub cover did not vary with percentage of ORV disturbance at the chosen significance level for our study, a negative relationship is apparent, including a significant difference in mean shrub cover between use and non-use areas. Decreased shrub cover in disturbed areas may explain the mechanism responsible for the lower abundance of *P. eremicus* in highly disturbed areas.

Another characteristic that may have contributed to the observed differences in abundance of *P. eremicus* is its association with cacti (Hoffmeister 1986). Though other genera were present in the study area, only *Opuntia* occurred frequently enough to consistently cross our vegetation transects. The significant decrease in *Opuntia* spp. in heavily disturbed areas may account for some of the associated decrease in *P. eremicus* abundance.

NEOTOMA ALBIGULA

Neotoma albigula is strongly associated with the presence of *Opuntia* spp., which is important both as a food source and as material for house construction (Hoffmeister 1986). In Arizona, *Opuntia* spp. is the most important food source for this rat (Vorhies and Taylor 1940). Additionally, *N. albigula* commonly builds its house under desert shrubs, with *Opuntia* spp. and *Parkinsonia microphylla* among those commonly selected (Hoffmeister 1986). Decreased abundance of *N. albigula* in ORV usage areas may be explained by the relative lack of shrub cover, and decreased incidence of *Opuntia* spp. and *P. microphylla* found in ORV usage areas as compared to non-disturbed sites. Failure of the t-test to return significant differences in *N. albigula* abundance is not consistent with regression model results, and suggests further study may be needed to better understand the effects of ORV use on this species.

CHAETODIPUS BAILEYI

Of all species studied, *C. baileyi* can best be described as a generalist, both in diet and habitat selection. The species is known to consume a wide variety of seeds; at times concentrating on shrub seeds (Reichman 1975), and at other times mostly forb and grass seeds (Stamp and Omhart 1978). When compared to some other species of heteromyid rodents (*Perognathus amplus*, *D. merriami*, C*. intermedius*), *C. baileyi's* diet is diverse (Reichman 1975). Hoffmeister (1986) finds that *C. baileyi* inhabits desert flats and slopes, in dense stands of grass, or in open areas, which may or may not be interspersed with rocks. It is possible that the ability to utilize a variety of habitats and food sources allows *C. baileyi* populations to adapt to ORV related landscape changes more successfully than some other rodent species. That *C. baileyi* was the only species captured at every sample location, and the most abundant species in the study area, supports this view.

MANAGEMENT IMPLICATIONS

It is possible that rodent populations in ORV areas are healthy and stable, with smaller abundances indicative of habitat selection preferences rather than direct negative impact on individuals. If true, then one might expect certain desert species that prefer more open habitat to thrive in ORV designated areas, replacing those species that require the denser vegetation found in habitats undisturbed by ORV recreation. Current study results are consistent with this hypothesis.

If certain wildlife is less abundant in ORV areas because those areas provide less available habitat rather than some direct influence on reproduction or survivorship, then it may be possible to offset negative impacts with intelligent design and placement of ORV recreation areas. For example, interspersing ORV trails with undisturbed patches of desert, and monitoring plant communities within a recreation area to ensure the continued presence of important species may mitigate some of the damage caused by ORV recreation. The success of any such management strategy would depend on active enforcement of laws requiring ORV riders to stay on existing trails, which may be unlikely.

Study results show that not only are certain species less abundant in ORV areas, but they decline continuously with increasing ORV use. Other management strategies could seek to limit disturbance within an area, perhaps by designing recreation areas for dispersed use, rather than allowing hot spots of ORV activity, as is currently the case in the Rolls ORV recreation area.

Future research goals should evaluate spatial effects of ORV use outside of designated areas. It is possible that wildlife abundance is not only depressed within usage areas, but declines in non-use areas with increasing proximity to ORV recreation sites. Such knowledge, used in combination with an understanding of how much ORV use a wildlife population can tolerate, would lead to more informed ORV management.

An important component of federal land reserves is the concept that all shareholders have an equal right to use the land. The activities of one shareholder should not override the rights of other users. Land managers have a duty to represent all shareholders, and when one group's activities prove particularly damaging to a local habitat, regulations should be in place to mitigate such damage. This study supports previous finding that ORV use damages both vegetation and wildlife, and provides evidence of this damage occurring in a popular recreation area serving the Phoenix metropolitan area. Tonto National Forest provides outdoor recreation opportunities for potentially millions of nearby residents and finding ways to minimize ORV associated habitat loss should be an important goal towards ensuring continued enjoyment of this land for all residents.

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APPENDIX A

IACUC ANIMAL PROTOCOL REVIEW

Institutional Animal Care and Use Committee (IACUC)
Office of Research Integrity and Assurance
Arizona State University

Tempe, Arizona 85287-1103
(480) 965-2179 FAX. (480) 965-7772

Animal Protocol Review

ASU Protocol Number:	**09-1057R**
Protocol Title:	**Effects of Off Road Vehicle Use on Small Mammal Populations in the Sonoran Desert**
Principal Investigator:	**Ward Brady**
Date of Action:	**04/23/2009**

The animal protocol review was considered by the Committee and the following decisions were made:

- ☒ The original protocol was APPROVED as presented.
- ☐ The revised protocol was APPROVED as presented.
- ☐ The protocol was APPROVED with RESTRICTIONS or CHANGES as noted below. The project can only be pursued, subject to your acceptance of these restriction or changes. If you are not agreeable, contact the IACUC Chairperson immediately.
- ☐ The Committee requests CLARIFICATIONS or CHANGES in the protocol as described in the attached memorandum. The protocol will be reconsidered when these issues are clarified and the revised protocol is submitted.
- ☐ The protocol was approved, subject to the approval of a WAIVER of provisions of NIH policy as noted below. Waivers require written approval from the granting agencies.
- ☐ The protocol was DISAPPROVED for reasons outlined in the attached memorandum.
- ☐ The Committee requests you to contact ________________ to discuss this proposal.
- ☐ A copy of this correspondence has been sent to the Vice President for Research.
- ☐ Amendment was approved as presented.

Pain Level: C **Species:** Various Small Mammals (see attachment)
Approval Period: 04/23/2009 – 04/22/2012

Signature: S Murphy Date 4/27/09
IACUC Chair or Designee

Original: Principal Investigator
cc: IACUC Office
IACUC Chair
ORSPA/SP

APPENDIX B

AZGFD SCIENTIFIC COLLECTING PERMIT

ARIZONA GAME & FISH DEPARTMENT

5000 West Carefree Highway, Phoenix, Arizona 85086

APPLICATION FOR SCIENTIFIC COLLECTING PERMIT (NO FEE)

CHECK ONE: **New** ☐ **Renewal** ☑

Name Simon Reid Phone (best # to be reached by) 480-458-8538

☑ Male ☐ Female Height (ft-in) 6ft - 0in Weight (lbs) 215 Eyes Green Hair Brown

Department ID # Birth Date March 6, 1980

Affiliation Arizona State University Department of Applied Biology

Job Title (or nature of affiliation with) Graduate student Phone (if different than above) 480-727-1444

Address 7001 E. Williams Field Rd.

City Mesa State AZ Zip 85212

Mailing Address (if different than above) 5826 N. Monte Vista Dr.

City Paradise Valley State AZ Zip 85253

E-mail Address jsreid1@asu.edu Fax

A proposal is required: e-mail scpermits@azgfd.gov for an electronic copy of the proposal form, or call 623-236-7625.

Provide the name, address, and telephone # where live wildlife will be held (if different than above) as well as a detailed description or diagram of the facilities where the wildlife will be held, and a description of how the facilities comply with Live Wildlife Rule R12-4-428.

If this is a renewal and you still have Arizona wildlife in captivity (in Arizona), you must provide a list of the species and numbers currently in captivity; all such individuals must be placed under a Wildlife Holding Permit (see Live Wildlife Rule R12-4-417).

By signing this application, I attest that my signature affixed to this application is authentic and the information provided on the application and proposal is true and correct to the best of my knowledge, and my or my agent(s) wildlife privileges are not revoked in this state, any other state, or the United States.

Signature: Simon Reid Date: 1-22-10

Mail to: Arizona Game & Fish Department
Nongame Branch- SCP Administrator
5000 W. Carefree Hwy
Phoenix, AZ 85086
Or fax to 623-236-7939

FOR DEPARTMENT USE ONLY

Date Received
Date Reviewer Received
\# of review days **# of total days**
Permit #: **Date Issued:**

FORM 18-A (Revised 11/2007)